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A study on functional and radiological outcome after corrective osteotomy and volar locked plate fixation for extra-articular malunion of distal radius

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Abstract
Background: Malunion is the most common complication following distal radius fractures occurring approximately 23% of non-surgically treated injuries and approximately 11% of operatively treated fractures. Malunion leads to functional limitation of affected wrist significantly requiring intervention. We report the functional and radiological outcome after corrective osteotomy of malunited distal radius using volar approach and fixation with a volar locked plate. **Material and methods:** Fifteen malunited distal radius in skeletally matured patients were treated with an osteotomy and iliac crest corticocancellous bone graft. Osteotomy was fixed in corrected position using a distal radius volar locking plate. Outcomes were evaluated using Modified Grahams criteria for acceptable healing, Fernandez scale, Modified Mayo wrist score and DASH questioner. **Results:** On radiological evaluation radial tilt was in the range of 9 degree dorsal to 20 degree volar. All osteotomies healed within acceptable limit by modified Graham's radiographic criteria of acceptable healing of distal radius fractures. Functional evaluation by Fernandez scale shows excellent result in 3, good in 7, 5 fair and no poor result. Modified Mayo wrist score assessment shows 4 excellent, 6 good, 5 satisfactory and no poor result. The average score is 78.67 (range 65-90). DASH questioner analysis postoperatively revealed the average score is 15.93 improved from preoperative mean 50.8. One patient required concomitant ulnar shortening osteotomy. **Conclusion:** Corrective osteotomy and volar locked plate fixation of distal radius for symptomatic malunion gives favourable radiological and functional outcome and should be carried out in patients with high functional demand of the wrist joint.

Keywords: Distal radius, malunion, osteotomy, volar plating, volar approach

1. Introduction
A normal wrist is very important for both manual labourer and fine work occupation. Disturbance in normal wrist biomechanics leads to pain causing trouble in workplace. Malunion of a distal radius fracture, that almost always occurs about 2.5 centimetre from the distal end of the bone at the corticocancellous junction [1] alters the normal wrist biomechanics. Fracture of the distal end of radius represent the most common fracture of the upper extremity comprising approximately 8%-17% of fractures seen in the emergency department [2] As per literature malunion is the most common complication following distal radius fractures occurring approximately in 23% of non-surgically treated injuries and in 11% of operatively treated fractures [3] and the incidence of clinically apparent malunions will likely increase in the future due to both the overall increase in distal radius fractures and the increased functional demands of a longer living adult population [4]. Pain at the wrist, decreased grip strength, decrease in range of movements are common symptoms after distal radial malunion. Loss of radial inclination increases stress at the radio-lunate articulation. 2.5 cm of radial shortening makes ulna to bear 42% of axial load, alters the congruency of DRUJ and increases tension at TFCC. Similarly, loss of normal palmar tilt increases strain on radioulnar ligaments. The need for operative correction of symptomatic, malunited fracture of the distal radius has long been recognized. The use of fixed angle distal radius low profile smooth locking plates for distal radius fractures lead to combining these with corrective osteotomy with or without bone grafting. In our prospective study, we tried to evaluate the functional out come and

radiological correction of malunited distal radius fractures after extra articular osteotomy with bone grafting and volar plating.

2. Material and methods

A prospective study was carried out after obtaining ethical clearance and consent in a tertiary hospital for a total of 15 cases of malunited distal radius fracture between 18 yrs. - 70 yrs. The study was conducted for a period of 2 years from July 2014 to June 2016. The inclusion criteria were those patients who gave consent to include in the study with symptomatic malunited distal radius fracture in patients aged 18-70 years with unacceptable radiographic parameters taking Modified Grahams radiological criteria for acceptable healing of distal radius [5] and competent neurological and vascular status of the limb. Here symptomatic means symptoms of pain in wrist during work or at rest, decrease range of movement of affected wrist and decrease grip strength compared to non affected side. Exclusion criteria were patient who did not give consent to include in the study, Patient aged <18 yrs. and >70 yrs., Intraarticular malunion, initial trauma of less than 8 weeks duration, malunion with degenerative joint diseases and stiffness of finger joints, radiological and clinical sign of reflex sympathetic osteodystrophy and radiological deformities within acceptable limit of Graham's radiological criteria. Older population were excluded due to less functional demand, osteoporosis, and higher chance of degenerative joint diseases. Original injuries were classified as Colles type (AO23A2.2) for malunion in dorsal angulation and Smith type (AO23A2.3) for volar malunion. All patients were followed up for minimum 12 months. Check X-rays were taken at 6 weeks, 9 weeks and at 3 months, 6 months to assess consolidation or collapse at the osteotomy site and to note any displacement. The fracture was considered united when clinically there was no tenderness, subjective complaints, and radiologically when the fracture line was not visible. All radiological indicators of outcome (volar tilt, radial inclination and ulnar variance) were noted at 3 months. Radiological outcome was assessed using modified Graham's criteria of acceptable healing. Functional evaluation was done at 3 months using Fernandez scale [6], Modified Mayo Wrist Sore [7] and DASH questioner [8]. Statistical analysis was performed to compare the pre and post-operative radiological and functional outcome. All the data were analysed by specific statistical test to various sets of data using the computer software 'Graphpad InStat3'. Paired t test was used for comparison of preoperative and post-operative measurements. P-values were calculated out and differences between the two groups were considered significant if the p-value was less than 0.05.

2.1 Operative technique

We performed preoperative templating using postero-anterior and lateral view X-ray of the normal wrist. Radiological measurements were taken for both the wrist joint by computed radiographic machine and correction required was calculated taking normal wrist as reference [Fig.1]. Under general or regional anaesthesia using pneumatic tourniquet osteotomy was done in volar approach [Fig.2] using distal extent of Henry approach between the tendon of the flexor carpi radialis and the radial artery and fixed with a 3.5 mm distal radius locking plate. In Smith type of fracture with union in $>20^0$ angulation volar plating was done by the technique as described by Shea *et al* [5]. First, we put one smooth 1.5mm k-wire perpendicular to the radial shaft proximal to planned osteotomy site. Second K-wire is inserted at desired angle of correction in the distal fragment of malunion [Fig.3]. In Colles type of malunion plate is provisionally fixed to distal fragment in correct position using k-wire/screw under fluoroscopy guidance and the level of osteotomy is planned [Fig.4a]. Plate is then removed and osteotomy is performed with an osteotome at the site of malunion [Fig. 4b]. Osteotomy gap is maintained with lamina spreader [Fig. 5]. Alternatively, external fixator frame is used [Fig.6]. Plate is first fixed to the distal fragment with screw and then to the distal fragment through oval hole in the plate and necessary adjustments are made under fluoroscopy guidance. We put 2 to 3 screws in proximal fragment and 3 screws in the distal fragment. The final position of the plate was confirmed using fluoroscopy. Corticocancellous iliac crest graft inserted at the osteotomy gap [Fig.7]. Post-operatively affected limb was kept elevated and patients were asked to perform active finger movements, elbow and shoulder movements from day one. Wound was inspected on the 4th post-operative day. The splints were discarded and replaced by an elastocrepe bandage and patients were advised to carry out routine activities within the elastocrepe bandage. Suture removal done at 10- 14th post-operative day. In non-compliant patients the splints were continued till the 1st or 2nd follow up. The patients were advised not to lift heavy weights for further 4 to 6 weeks.

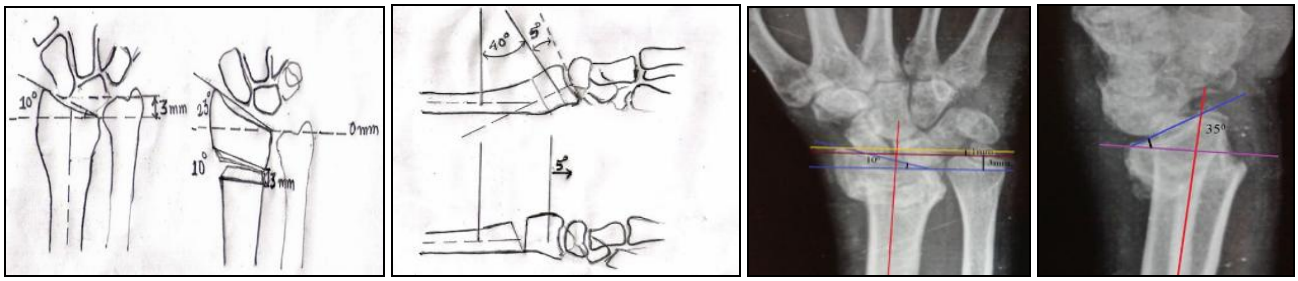


Fig 1: Preoperative calculation of required correction using postero-anterior and lateral view X-ray of both wrist

Fig 2: Exposure of malunion by volar approach Figure3. K-wire inserted at the desired angle of correction in distal fragment

Fig 4.a: Plate is provisionally fixed to distal fragment with a screw under fluoroscopic guidance b. Completing and levering osteotomy with osteotome

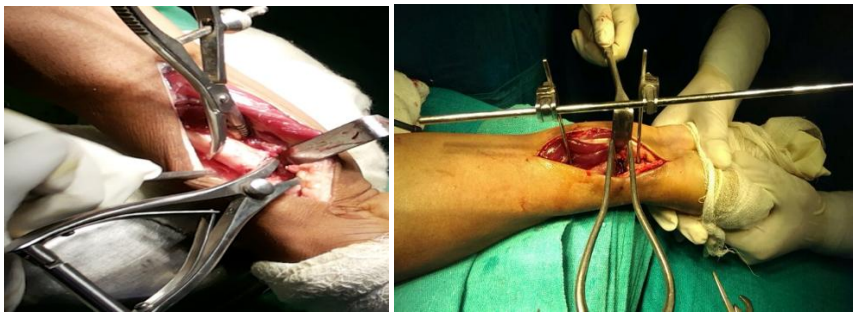


Fig 5-6: Correction achieved is temporarily held with a lamina spreader or a mini external fixator frame

Fig 7: Insertion of cortico-cancellous iliac crest bone graft at osteotomy gap

3. Results

Maximum numbers of patients [6] were in the age group of 41-50 years. The mean age of the whole study group was 42.9 years. Males outnumbers female by a ratio of 2.2:1 for the study population. Right side [12] was more commonly involved than the left side. The commonest mode of injury was found to be road traffic accident [8].

The original fractures were classified as per AO classification system. Accordingly there were 11 type 23-A2.2 fractures (Colles type) and 4 type 23-A2.3 (Smith type) fractures. There were no associated injuries. Most of the cases [6] were initially treated by close reduction and cast immobilization.

The average time interval between trauma and the surgery was 18 weeks (range 8 to 48 weeks). In most of the cases (46.67%) presentation was early and operation was done between 8 to 12 weeks after initial trauma after subsidence of pain and inflammation and giving physiotherapy for range of motion. The mean operative time was 69 minutes. Ulnar shortening osteotomy required in one patient intraoperatively due to excessive positive ulnar variance causing difficulty achievement of reduction. We performed cuff resection and fixation with a small DCP.

Radiological criteria were within the acceptable limits in all the cases by Graham's radiological criteria of acceptable healing in most of the cases postoperatively with functional improvement. The mean preoperative dorsal tilt in the Colles group was 31.18 degrees (SD 6.06) and mean preoperative volar tilt in the Smith group was 27.5 degrees (SD 8.67). After post-operative evaluation in the Colles group in 5 patients there was a residual dorsal tilt of average 6 degrees (range 3-9), in 3 patients there was a volar tilt of average 9.3 degrees (Range 3-20) and in 3 patients radial tilt was neutral. Two patients had residual dorsal angulation of 9 degrees and one had overcorrection to 20 degrees' volar tilt. In the Smith group 3 patients had volar tilt of average 6.6 degrees and one patient had neutral angulation. Mean radial inclination was 19.46 degrees (SD 3.06) post operatively. Radial height improved from mean preoperative value -0.13 mm to 9.73mm

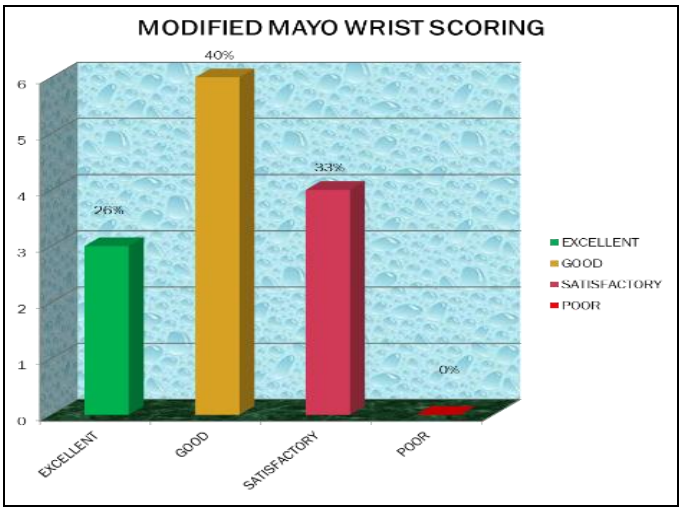
postoperatively. Postoperatively mean ulnar variance was 0.27 mm.

The functional results were evaluated using 3 different scoring systems that include Fernandez scale, Modified Mayo wrist score and DASH questioner. There is a statically significant (p=0.0001) improvement in palmar flexion from 32.72 degree preoperative to 63.64 degree postoperatively in Colles group. Dorsiflexion is significantly improved from 54.09 degree in Colles group and 25 degree in Smith group to postoperative 67.27 and 65 degrees respectively. Though radial deviation improved in both group it was not statistically significant. The ulnar deviation improved significantly (p= 0.0027 in Colles and p= 0.006 in Smith) from preoperative 17.27 in Colles group and 20 degree in Smith group to postoperative 28.63 and 28.75 degree respectively. Supination improved in Colles group from mean 58.63 degree to 75.45 degree (p=0.0001) and in Smith group from 66.25 degrees to 73.75 degree (p=0.013). Similarly pronation improved significantly from preoperative mean 60 degrees in Colles group to postoperative 73.18 degrees (p=0.0007) and in Smith group from 67.5 degrees to 75 degrees (p=0.013). There was significant reduction in pain intensity or complete elimination of pain post operatively when we used Visual Analogue Scale to measure preoperative and postoperative pain intensities.

Functional evaluation by Fernandez scale shows excellent result in 3, good in 7, 5 fair and no poor result. Modified Mayo wrist score assessment showed 4 excellent, 6 good, 5 satisfactory and no poor result [Fig.8]. The average score was 78.67 (range 65-90). DASH questioner analysis postoperatively revealed the average score was 15.93 improved from a preoperative mean 50.8.

No intra-operative complication was noted in our study. 1 case of superficial infection was noted that resolved after conservative treatment with antibiotics. Implant was removed in the same patient after 9 months as he was complaining of tendon irritation during work. In our study, we found no cases with deep infection, malunion, non-union, tendon rupture or Sudeck's atrophy.

The demographic profiles of the patients and results are summarised in Table 1 and 2 respectively.



Modified Mayo Wrist Score:

Pain intensity	Functional status	Range of motion	Grip strength
No pain (25)	Returned to regular employment (25)	100% (25)	100% (25)
Mild, occasional (20)	Restricted employment (20)	75-99% (15)	75-99% (15)
Moderate (15)	Able to work but unemployed (15)	50-74% (10)	50-75% (10)
Severe (0)	Unable to work due to pain (0)	25-49% (5)	25-50% (5)
		0-24% (0)	0-25% (0)

Result: a) Excellent- 90-100 b) good- 80-90 c) satisfactory- 60-80 d) poor- ≤ 60

Fig 8: Modified Mayo wrist score outcome

Table 1: patient demographic profile

Sl no.	Age (Year) sex	Mode of injury	Limb D/A	Fracture type	Primary treatment	Time interval between injury to osteotomy(months)	Anaesthesia.	Bone graft	Ulnar shortening osteotomy
1	55 F	FFH	R/R	C	QT	3	GA	YES	No
2	45 M	RTA	R/L	C	UT	4	GA	YES	Yes
3	30 F	RTA	R/R	S	C	12	GA	YES	No
4	23 M	PA	R/R	C	QT	$2^1/_2$	RA	NO	No
5	52 F	F	L/L	C	UT	3	RA	NO	No
6	40 M	RTA	R/L	C	C	6	RA	NO	No
7	32 M	RTA	R/R	C	C	$5^1/_2$	GA	YES	No
8	49 M	FFH	L/ R	C	QT	$2^1/_2$	RA	NO	No
9	50 M	RTA	R/ R	C	C	7	GA	YES	No

10	50 M	RTA	R/ R	S	UT	8	GA	YES	No
11	52 F	F	R/ R	C	K	3	RA+SGA	YES	No
12	38 M	RTA	R/ R	C	L	3	RA+SGA	YES	Yes
13	43 M	FFH	R/ R	S	C	4	GA	YES	No
14	35 M	RTA	R/R	C	C	$2^1/_2$	RA +SGA	YES	No
15	50 M	F	R/R	S	UT	5	GA	NO	No

Note: D- Dominant, A- Affected, RTA- road traffic accident, FFH- fall from Height, F- Fall, PA- physical assault QT- Quack treated, UT- untreated, C-Cast, K- K wire, L- Locking plate

Table 2: pre and postoperative measurements

Sl no.	Preoperative/postoperative (in mm & degree)												
	Dorsal tilt	Volar tilt	Radial inclinationnn	Ulnar variance	Radial height	extension	flexion	Ulnar deviation	Radial deviation	pronation	Supination	Grip strength (kg)	Pain VAS
1	30/9	-	-10 /11	+1/ +2	-5/ 0	40/60	20/55	15/30	20/15	55/65	65/75	10/35	+++/+
2	35	-/ 2o	5/23	+3/ 0	1/ 12	45/65	35/65	10/30	5/20	55/70	50/65	12/45	++/0
3	-	40/11	10/21	+5/0	-4/ 10	10/70	70/70	15/25	5/20	70/80	65/70	15/40	+/0
4	40/8	-	5/ 22	+3/ +1	2/ 10	70/70	45/60	20/35	30/20	55/80	65/75	15/35	++/0
5	33/3	-	-12 /16	-5/-1	-4/ 9	50/70	40/70	15/30	20/15	70/80	55/75	6/30	+++/0
6	32/0	-	15/22	-2/-1	7/ 13	65/70	30/65	25/30	15/15	50/70	60/75	15/30	++/+
7	20/0	-	12/ 17	+2/0	5/ 10	35/65	40/65	5/20	30/20	60/65	55/70	20/40	+/+
8	30	-/4	3/ 21	+7/ +2	-5/ 11	40/60	40/55	15/30	5/15	65/80	60/80	20/40	++/++
9	25/9	-	7/ 20	+2/ +1	2/ 9	60/65	40/70	25/35	15/10	70/80	40/80	10/50	++/0
10	-	25/0	3/ 22	+7/-1	-5/ 12	30/65	60/65	20/30	10/15	60/70	65/75	10/40	++/0
11	40/0	-	4/ 19	+6/0	-4/ 10	80/75	30/65	30/15	10/25	70/70	60/80	10/25	++/0
12	32	-/4	10/20	+4/0	-4/ 10	60/75	30/65	15/30	20/15	40/70	70/75	12/40	++/+
13	-	25/5	10/18	+1/0	5/ 11	35/60	65/75	20/30	15/20	65/70	70/80	10/28	++/+
14	26/4	-	13/ 21	+4/ +1	2/ 9	50/65	10/65	15/30	10/10	70/75	65/80	20/30	+++/+
15	-	20/4	14/ 19	+3/0	5/ 10	25/65	60/70	25/30	10/15	75/80	65/70	20/35	+/0

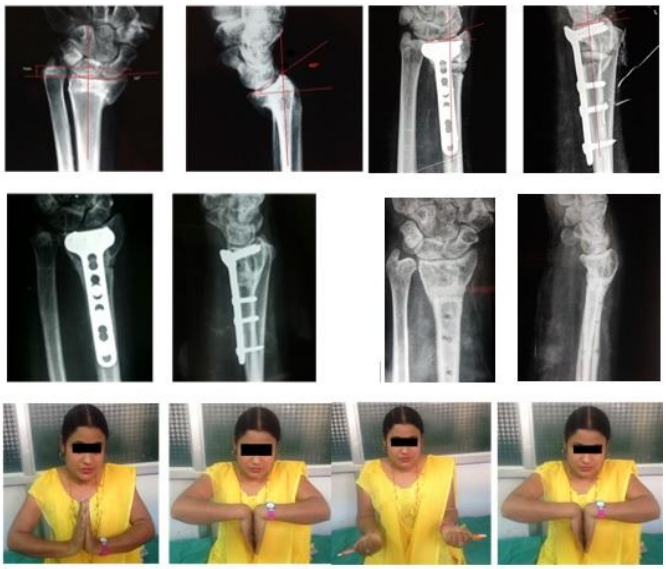


Fig 9: A volar malunion preoperative, immediate post-operative, 3 months, 6 months, 12 months follow up till implant removal with full functional recovery.

Fig 10: A dorsal malunion preoperative, 6months post operative and wrist movement

4. Discussion

Malunion of the distal radius is a common complication after distal radius fracture which can cause serious disability. Malunion can occur even after cast or surgical treatment due to gradual loss of reduction. Good reduction and anatomic union is utmost important. In dorsal malunion due to the loss of palmar tilt shifts the carpus distally on the radius, thereby increasing contact stress on the dorsal lip of the radius. In addition, the loss of radial inclination results in increased stress at the radio lunate articulation [9]. Dorsal angulation also results in increased strain on the radioulnar ligaments. Because of this increased strain, extra force is required to achieve full rotation of the forearm. The dorsal deformity of the distal radial articular surface can also result in a fixed carpal malalignment in dorsiflexion-a dorsal intercalary segment instability (DISI) [17]. In the normal wrist, approximately 82% of the axial load is distributed onto the radius with the remaining 18% born by the distal ulna through the triangular fibrocartilage complex. With 2.5-mm radial shortening, this relationship changes so that the ulna bears 42% of the axial load [10]. Radial shortening of 10 mm reduced forearm pronation by 47% and supination by 29% [11]. The malunited palmar bending fracture (Smith's fracture) present with an increased palmar tilt and a pronation deformity of the distal fragment that favours dorsal subluxation of the ulnar head. This will lead to limitation of active wrist extension and limitation of forearm supination.[11] Thus malunion of the distal radius can cause pain, stiffness of wrist and fingers, gross loss of range of movement and grip strength. Therefore, surgical correction of the malunion is extremely important. In our study surgical correction improved function of the wrist in most of the patients. Still residual deformity can exist in some of the cases. So prevention is still better and important to avoid having to treat malunion as stated by Flinkkila *et al* [12].

There are controversies regarding timing of osteotomy. The average time interval between trauma and the surgery was 18 weeks (Range 8-48 weeks) in our study. In most of our cases the presentation was early and we operated after minimum 8 weeks from initial trauma. We advocated preoperative physiotherapy to overcome stiffness of fingers and subsidence of the acute inflammatory process. Pillukat T *et al* (2013) [13] stated that although no statistical difference was detectable early corrective osteotomy seems to be recommendable in early presenting patients, in order to avoid bone-grafting. In later presenting cases they recommend observation and return after 6 months in the case of persistent pain or disability. As mentioned by Jesse b. Jupiter and David Ring [14] we did not find difference in outcome in early and late correction.

Controversies also exist regarding approach to correction of distal radial malunion. We performed volar plating using Henry approach in all our cases. Many researchers stated that dorsal plating is associated with tendon complications like tendon rupture, tendon irritation etc. We did not encounter any difficulty in addressing dorsal malunion through volar approach. Brett Peterson *et al* [15] commented that distal radius deformity can be effectively addressed through a volar approach with the use of a locking plate. Esin Rothenfluh *et al* [16] compared the results of volar (palmar) osteotomy and fixation with dorsal osteotomy and fixation. They concluded that corrective osteotomies of distal radius malunions can be done in either way. It might result in some better flexion, if performed volarly. The most common side effects listed for volar approach are median nerve injury, flexor tendon dysfunction and complex anatomy in volar site. We didn't encounter any such complications during volar approach.

We performed ulnar shortening osteotomy (cuff resection) in one patient due to excessive positive ulnar variance and difficulty in anatomical restoration of distal radius fragment. After osteotomy the ulna was fixed with a plate. J N Brown and M J Bell [17] commented that in some instances it was not possible completely to restore radial length without a reduction in ulnar length. J Oskam *et al* [18] reported on the effect of concomitant ulnar shortening osteotomy with corrective osteotomy for malunion of the distal radius. They concluded that if problems of restoring radial length are to be expected, a concomitant ulnar shortening osteotomy should primarily be performed.

We got one fair result due to inadequate reduction and gradual loss of correction achieved. We found 1 case with superficial infection at the surgical site. Fortunately the infection healed uneventfully on conservative treatment with regular dressing and antibiotics. One female patient developed hypertrophic scar at the incision site which was a cosmetic concern for her. One patient with volar plate fixation complaints of extensor tendon irritation by screw end for which we removed the implant 9 months postoperatively. There was no other major complication.

5. Conclusion

Careful patient selection and preoperative planning are two most important factors in outcome. Surgical approach using distal limb of Henry's approach for radius provides good visualization of the osteotomy site for volar approach and

dorsal malunion can be corrected by volar approach. Results of early and late reconstruction of malunited fractures of the distal end of radius are comparable. We will conclude that extra articular malunion of distal radius in young adult with high functional demand of wrist treated with corrective osteotomy and volar plating with bone grafting gives good functional and radiological outcome.

We acknowledge that with more number of cases in this study the results and observations would have been more accurate and statistically significant

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